Proton Radiation Testing of Laser Optical Components for NASA Jupiter Europa Orbiter Mission

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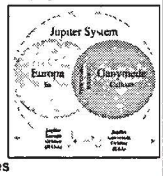
SPIE Optics and Photonics 2011
http://photonics.gsfc.nasa.gov

Overview

- EJSM Mission and Europa
- Proton Testing at Indiana University Cyclotron Facility (IUCF)
- Samples Tested
- Results
- Visual Inspection
- Conclusions

Europa Jupiter Science Mission (EJSM)

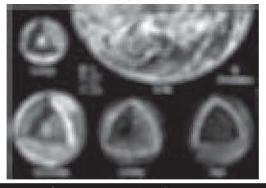
- NASA and ESA: Shared mission leadership
- Independently launched and operated orbiters
  - NASA-led Jupiter Europa Orbiter (JEO)
  - ESA-led Jupiter Ganymede Orbiter (JGO)
- Complementary science and payloads
  - JEO concentrates on Europa and Io
  - JGO concentrates on Ganymede and Callisto
  - Synergistic overlap
  - 11-12 instruments each
- Science goals:
  - Icy world habitability
  - Jupiter system processes

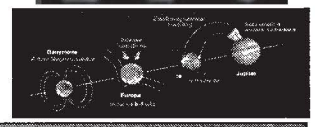


Synergistic science: The sum of JEO + JGO is greater than the parts

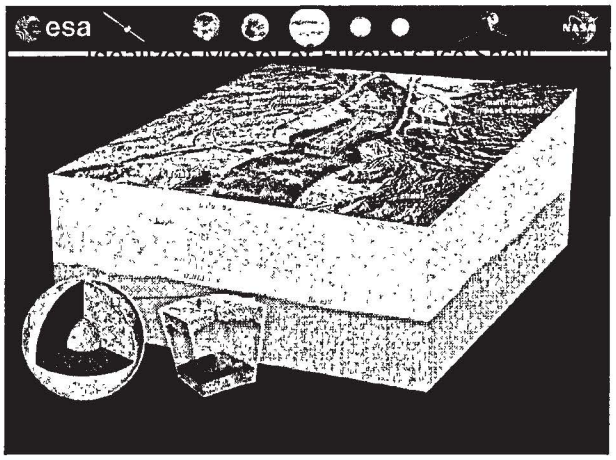
EJSM Theme:
The Emergence of Habitable Worlds Around Gas Giants

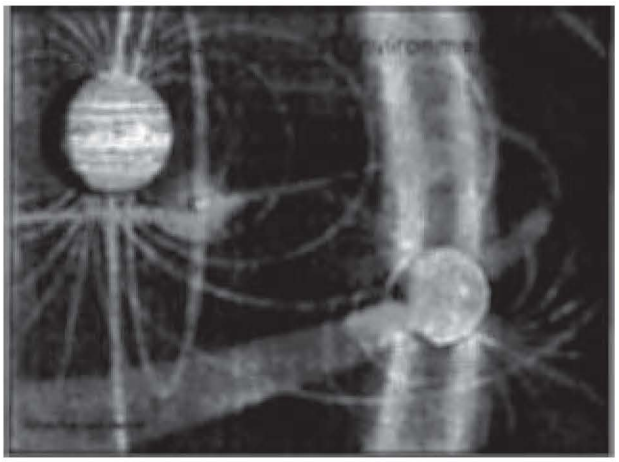
- *Goal 1:* Determine if the Jupiter system harbors habitable worlds
  - Ocean characteristics
  - Ice shells and subsurface water
  - Deep internal structure, and (for Ganymede) intrinsic magnetic field
  - External environments
  - Global surface compositions
  - Surface features and future landing sites
- *Goal 2:* Characterize Jupiter system processes
  - Satellite system
  - Jupiter atmosphere
  - Magnetodisk/magnetosphere
  - Jovian system interactions
  - Jovian system origin

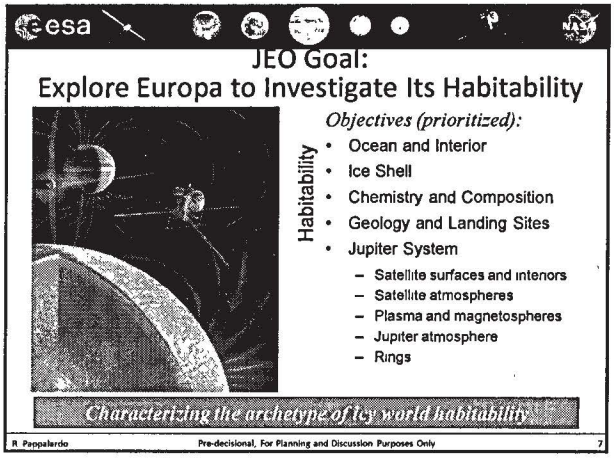




Emphasis on icy moon habitability and Jupiter system processes



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JEO Goal:
Explore Europa to Investigate Its Habitability
Objectives (prioritized):
Habitability
• Ocean and Interior
• Ice Shell
• Chemistry and Composition
• Geology and Landing Sites
• Jupiter System
– Satellite surfaces and interiors
– Satellite atmospheres
– Plasma and magnetospheres
– Jupiter atmosphere
– Rings
Characterizing the archetype of icy world habitability
R. Pappalardo
Pre-decisional, For Planning and Discussion Purposes Only
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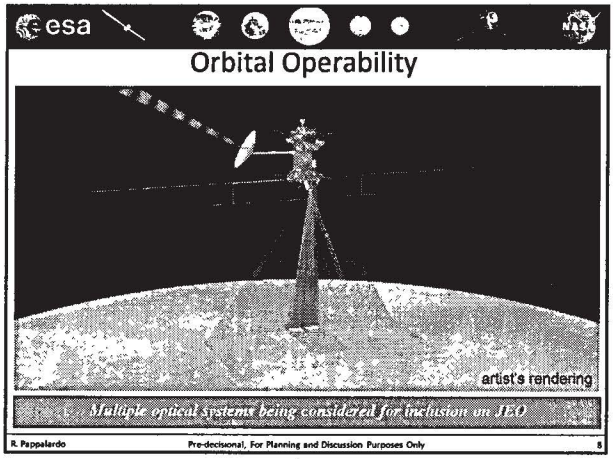
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Orbital Operability
artist's rendering
Multiple optical systems being considered for inclusion on JEO
R. Pappalardo
Pre-decisional, For Planning and Discussion Purposes Only
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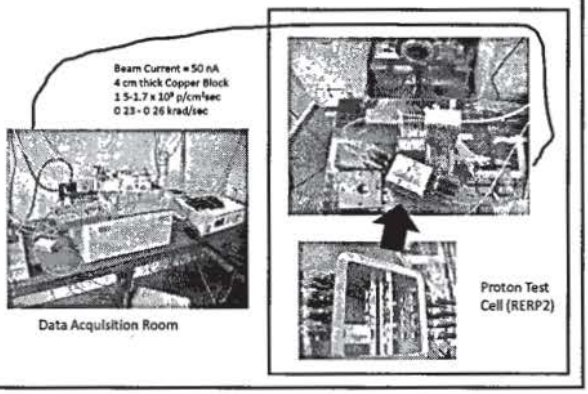
JEO Radiation Environment

- Four major sources of radiation
  - Solar energetic particles during interplanetary cruise (protons, electrons, and heavy ions)
  - Galactic cosmic rays during interplanetary cruise (protons and heavy ions)
  - Trapped particles in Jovian magnetosphere during Jovian tour and orbits of Europa (electrons, protons, and heavy ions)
  - Particles from onboard nuclear power source (neutrons and gammas)
- The high-energy trapped electrons and protons are dominating contributors to Total Ionizing Dose (TID) and Displacement Damage Dose (DDD)
- Expected radiation dose is 2.9 Mrad (Si) behind 100 mil Al
- Proton testing chosen as an initial screening

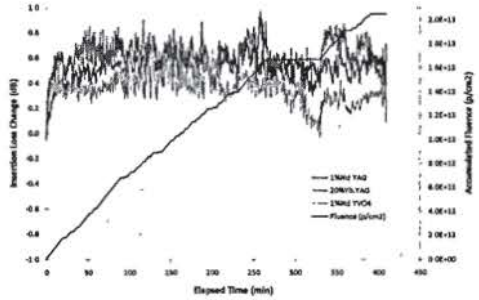
Optical Components for Proton Testing

Component	Designation	Material
Crystalline Laser Rod	Nd YAG	Neodymium-doped yttrium aluminum garnet
Filters	1064 nm bandpass filter	Bandpass filter
	532 nm bandpass filter	Bandpass filter
Q-Switch	KD*P Q-switch	Potassium dideuterium phosphate Q-switch
Polycrystalline (ceramic) Laser Rod Materials	1%Nd YAG	Neodymium-doped yttrium aluminum garnet
	1%Nd 0.5%Cr YAG	Neodymium-chromium co-doped yttrium aluminum garnet
	1%Nd 0.5%Ce YAG	Neodymium-cerium co-doped yttrium aluminum garnet
	20%Yb YAG	Ytterbium-doped yttrium aluminum garnet
	20%Yb 0.5%Cr YAG	Ytterbium -chromium co-doped yttrium aluminum garnet
	20%Yb 0.5%Ce YAG	Ytterbium -cerium co-doped yttrium aluminum garnet
	1%Nd YVO_4	Neodymium-doped yttrium orthovanadate

IUCF Proton Test Setup



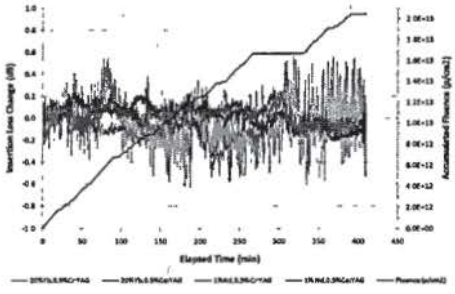
Ceramic Laser Rod Samples



Measured at 1064 nm

Ceramic Laser Rod Samples

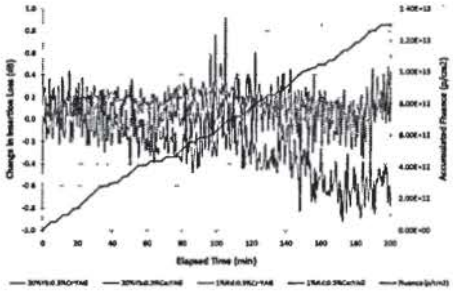
Co-doped Samples 1st Exposure



Measured at 1064 nm

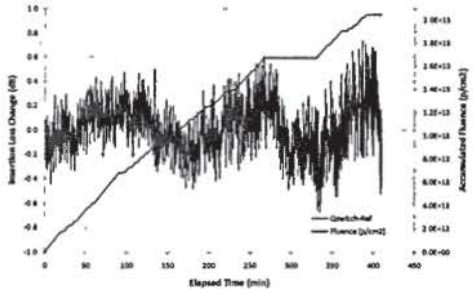
Ceramic Laser Rod Samples

Co-doped Samples 2nd Exposure



Measured at 1064 nm

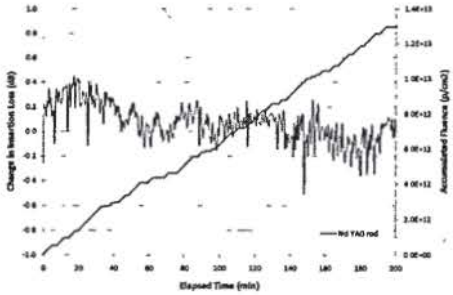
KD*P Q-Switch Sample



KD*P Q-Switch from Cleveland Crystals (Gooch & Housego Company), Model Impact 8

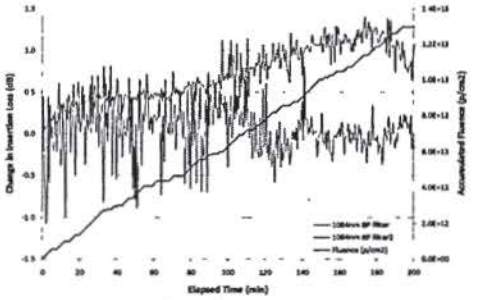
Measured at 1064 nm

Nd:YAG Laser Rod



Measured at 1064 nm

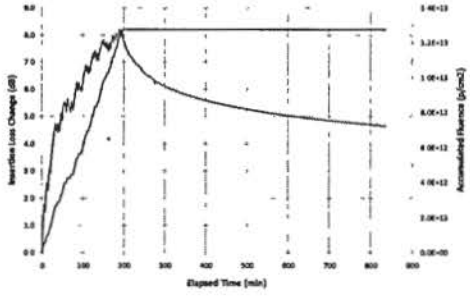
1064 nm Bandpass Filters



Measured at 1064 nm

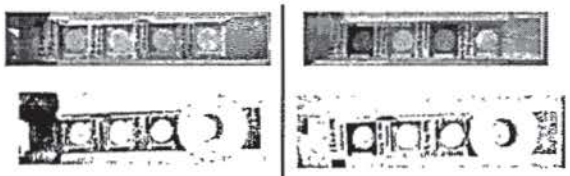
Filter 2 was only other sample connected to splitter used to monitor ceramic laser sample that showed ~1dB gain during second proton test. Loss in filter2 may be result of fiber splitter instability

532 nm Bandpass Filter



Measured at 532 nm

Visual Inspection of Samples



Before exposure | After Proton Exposure

Samples showed significant darkening in the visible wavelength ranges even though most exhibited little proton-induced optical transmission loss at 1064 nm

Conclusions

- Several standard laser materials and some polycrystalline (ceramic) laser materials irradiated at proton fluences in the 1-2 x 10^{13} p/cm^2 range (2-3 Mrad)
- Most materials showed little to no radiation-induced darkening at 1064 nm
  - Co-doped ceramic samples showed no significant darkening
  - Single-doped ceramic samples showed initial loss of 0.4-0/6 dB, which stabilized for remainder of test
  - Nd:YAG and KD*P Q-switch showed no significant darkening
- Most materials exhibited photodarkening at visible wavelengths
  - 532 nm bandpass filter showed large 8 dB loss during proton exposure

For additional information please see our website
http://photonics.gsfc.nasa.gov